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THE CONTRIBUTIONS OF
WILLIAM FREDERICK DURAND
TO AERONAUTICS

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Introduction

In these hurried days of the present as we press toward new scientific knowledge, toward new technology, and toward new human experiences in interplanetary space, we do well to review from time to time the work of those who blazed the trail. We are met to pay tribute to one of those pioneers, William Frederick Durand, a great engineer, outstanding teacher, notable writer and editor, wise counselor, leader, and beloved statesman. We had so much hoped to have him with us today, but he slipped away quietly and modestly on August 9, 1958. He would have completed his hundredth year on March 5th last.

In reply to an inquiry Dr. Durand once stated that his special interests have lain chiefly in the application of mathematics to problems in engineering and in experimental research aimed to serve as foundation for the treatment of engineering problems through formulae or other like mathematical methods. The pursuit of these interests led him into various fields of engineering and effectively to four intertwined careers in marine engineering, mechanical engineering, hydraulic engineering, and aeronautical engineering. Today we would designate his primary field of interest as engineering science, and we recognize in the further development of the mathematical approach supported by experimental research the tools which can lead us to interplanetary travel and advanced technological accomplishments in other fields. The Durand Centennial Conference on Aeronautics and Astronautics aims to honor a pioneer in the use of those methods for attacking the frontier problems of his time by further development and application to the frontier problems of engineering of our time.

My own part in the program of the Conference is to try to recreate for you some of the atmosphere, the enthusiasm, the sense of urgency, the boldness of attack, and the relationship to national needs of Durand's contributions to the aeronautical field.

Pre-Aeronautical Period

His very first contribution to the technical literature at the age of 21 was in a way prophetic of his later work in ship propulsion, with particular relation to the screw propeller as a means of propulsion, both for ships and aircraft. It was a letter to the editor of the Army-Navy Journal [1] entitled "Proper Proportion of Ships," a criticism of a published article on ship propulsion. Durand's researches on the screw propeller, extending (with intermissions) from 1892 to 1926, are his most important contribution in the field of science.

In 1891 Cornell University established a new School of Marine Engineering and Naval Architecture and invited Durand to become its head. Ever since his naval service on the cruiser Tennessee, he had been interested in the screw propeller and the theory of its operation. With a grant from the Carnegie Institution of Washington, a canal of the Cornell Hydraulic Laboratory was fitted as a towing basin for propeller testing. His investigation of some 49 models of systematically varied designs was the most detailed and comprehensive carried out up to that time. The results were published in 1907. [2] We shall see that this line of research was later transferred to aircraft propulsion.

Durand and the National Advisory Committee for Aeronautics

Durand became professionally interested in aeronautics at the age of 55. His interest in aeronautics came as did that of many others, including myself, as a direct consequence of the establishment of the National Advisory Committee for Aeronautics. The drive for a national aeronautical research laboratory began in 1911, but Durand was first associated with it when he attended a conference in Washington in 1914 at the invitation of Dr. Charles D. Walcott, secretary of the Smithsonian Institution. The NACA was established by a rider on the Naval Appropriations Act, approved March 3, 1915 and on April 2, 1915 Durand was appointed a member of the new 12-man committee. The first meeting was held on April 23, 1915. At this meeting Durand set forth the need for research on the air propeller, the proposal stemming directly from his work at Cornell on marine propellers.

CASE FILE COPY

On June 15, 1915 Dr. Durand received the following wire from H. C. Richardson, Secretary of NACA:

Please report by wire whether or not you are willing to enter into an investigation on the following subject and submit printed report to the National Advisory Committee for Aeronautics on same on or before October thirteenth of this year, and quote figure at which you are willing to enter into a contract to furnish same. If you can make substantial progress without completing investigation by date set, so state and quote figure for preliminary report by date set. Report on means of attaining maximum efficiency in propellers normal flight, on effects on efficiency at altitudes of eight thousand feet to ten thousand feet compared to efficiency at surface, taking account of increased velocity of aeroplane required for sustentation in the rare atmosphere.

Durand replied as follows:

Telegram of 15 carefully considered. Understand experimental investigation contemplated. No apparatus suitable here at present. Consider following minimum time and expense required. Time for construction and installation of apparatus three months. Time to make investigation and prepare report on propellers normal flight, three months. Cost of general experimental equipment \$2000. Cost of propeller models and of making investigation \$3000. University will furnish quarters for equipment. Above investigation not exhaustive but sufficient to indicate clearly the general character of results to be expected and direction for further detailed research.

Investigation for efficiency under decreased density would probably require \$1000 additional expense for equipment and \$1200 for running experiment, reducing results and making report. All estimates based on services of Lesley in immediate charge with my general supervision. Lesley and crew only under pay. Should be glad to undertake investigation under general conditions outlined above, but do not feel that enough to form more than a preliminary report of progress could be made before Oct. 13. Letter follows.

In the letter which followed Durand's closing paragraph reads:

As a matter of curiosity I am interested to inquire regarding the possible source of funds for such an investigation or for any investigation in fact, in advance of a further appropriation from Congress.

It seems that on June 15 as a result of the lateness of the passage of the Naval Appropriations Act and the time required to establish rules of procedure, a sum of \$4000 was available to be obligated before July 1, i.e. within two weeks. Decision was made to support five small contracts in lieu of the propeller investigation. However revised estimates were submitted in February 1916 followed by a formal submission and award of the contract in October 1916 after approval of the appropriation bill for the next fiscal year.

Durand was elected chairman of NACA at the annual meeting in October 1916, but continued in residence at Palo Alto. In those days the business from day to day was conducted by the Executive Committee of which Walcott was chairman. Durand and his colleague E. P. Lesley proceeded with the installation of the wind tunnel and construction of the model propellers during the fall and winter of 1916-17. There was much discussion in correspondence between Durand and others regarding the best type of wind tunnel. Durand inclined toward the Eiffel form and adopted it.

In April of 1917 the United States entered the war and Durand came to Washington to become deeply involved in the war effort. About half time was given to the NACA and half time to the Engineering Section of the National Research Council. At about this time the National Academy of Sciences elected Durand to membership, along with two others, the first engineers to be elected to the Academy and the nucleus of the present Engineering Section.

In May Durand wrote to a friend that he had been in Washington since April "where I seem likely to remain so long as present conditions exist. My work is intensely interesting but represents a tremendous rush and whirl and requires a good many more hours of work per day than I have normally been putting in. However it is all a part of the war game and only what we must expect, especially in the early days of relative disorganization and confusion. Hoping, however, that the good time will come when we can forget about these things and get back to our peaceful knitting, I am ----."

Throughout the great confusion of Washington, Durand carried on an extensive correspondence with Lesley, directing the propeller project in detail, giving instructions for additional measurements, and for sending the results to him in Washington. Thus in July 1917, he asked Lesley to send him sketches of blade sections with a view to having the blades figured over here according to the "drink whiskey" method. It takes an old timer to recognize the "drink whiskey" method of designing propellers. It was developed in 1909 by a Polish engineer named Drzwiecki. His name, when pronounced correctly, sounds something like "drink whiskey."

Lesley came to Washington in the fall to assist Durand with the preparation of the report entitled "Experimental Research of Air Propellers" which appeared as Technical Report No. 14 in the Third Annual Report of the NACA submitted to the President by Chairman Durand on December 3, 1917. This report was followed by nine others over the next nine years extending the scope to other models, to effects of inclining the propeller axis, to propeller-body interactions, and to comparisons with flight tests on the one hand, and with airfoil theory on the other. These reports were the authoritative sources for design data and for instructional purposes for many years.

Aeronautical Leader in World War I

As Chairman of NACA Durand made many outstanding contributions to governmental policy on many important matters. The Committee operated through some twenty-five subcommittees, on ten of which Durand served. He was chairman of four. All reported to the Executive Committee of which he was a member. The Executive Committee functioned in accordance with general instructions of the NACA, of which he was chairman.

To mention a few of his important accomplishments in this period, he was a primary force in the establishment of the NACA Laboratory at Langley Field, he designed the first NACA wind tunnel, he induced colleges, universities, and technical schools to organize ground school training courses for military aviators, he organized the first Air Service flight training program using Canadian flyers as instructors, he dealt successfully with troublesome patent problems which were hampering aircraft production, he directed the consideration of thousands of aeronautical inventions submitted to the government.

Durand describes his work on the patent problems in his autobiography [3] as follows:

The effort to build up a fleet of aircraft was, at the first, much hampered by questions arising out of the aircraft patents. Individual interests were naturally ^{clearly} ~~decisions~~ of drawing such advantage as they might from such patents as they might hold. This very much tangled up plans for the prompt and effective construction of such planes as our industry seemed best qualified to undertake. To seek a remedy for this condition a conference of all the leaders in the aircraft industry was called in Washington by the NACA.

Here, after several sessions a plan was devised and adopted, called the Cross-License Agreement. This plan represented, practically, a pooling of all important aircraft patents with suitable provision for common use, for the period of the war, by the industry at large. It relieved the situation arising out of aircraft patents, and was an important contribution to our early efforts to build up a war purpose aircraft industry.

This is a calm recital of what others remember as somewhat turbulent negotiations. In fact in a letter written September 4, 1917 to Dr. Walcott who was then climbing glaciers, Durand wrote: "We are just now having a merry round with the Aeronautical Society of America regarding the Manufacturers Aircraft Association and the cross-licensing agreement."

Sometime during 1917 Durand had his first airplane flight in an Italian triplane bomber from Langley Field to Washington. He describes his impression of this first flight at some length in his autobiography and becomes for a time the master teacher to explain the illusions associated with banking of an airplane.

Retirement Brings New Opportunities

In January 1918 Durand became Scientific Attache' to the U.S. Embassy in Paris for liaison activities on applications of science to warfare. While abroad he gave the Wright Memorial Lecture before the Royal Aeronautical Society in London on the topic "Outstanding Problems in Aeronautics." A few months after the close of the war he returned to Stanford to teaching, research, and consulting, remaining as a member of NACA until 1933. In 1924 he was retired from

Stanford at the age of 65 but continued his research on propellers for the next two years. In 1925 he served as member and secretary of the Morrow Aircraft Board whose report set forth a proposed plan of development of military aircraft for the immediate future and recommended the creation of offices of Assistant Secretary for Military and for Naval Aircraft.

In the same year Durand accepted the invitation of Mr. Daniel Guggenheim to become a trustee of the Guggenheim Fund for the Promotion of Aeronautics, an event that was to lead to a most important contribution to aeronautic science. This is the series of monographs on the general subject of Aerodynamic Theory. Durand conceived and planned the project and agreed to supervise its ^{planning} ~~planning~~, preparation, and publication. From 1929 to 1936 this was his principal occupation. This series of twenty divisions in six volumes with a total of about 2200 pages is known all over the world. Durand was author of three of the divisions, and as I know from personal experience worked closely with the authors on every detail from plans to final proof to assure an integration of the twenty divisions into a unified whole with consistent notation and a final product as free from error as possible.

American book publishers were uncertain about the sales and were unwilling to assume the risk. Accordingly the series was published by Springer in Germany. The edition was soon sold out. After World War II began, there was a large demand for copies because the contents were of enduring interest in aeronautical education and engineering practice. Since no more volumes were available, a limited private company was formed at the California Institute of Technology to reproduce the entire work by the photo-offset process.

Return to Service -- An Elder Statesman in

Old and New Fields of Technology

When Aerodynamic Theory was first published in 1936, Durand was 77 years old. A year later he was appointed Chairman of a Special Committee on Airships, a committee created by the National Research Council at the request of the Secretary of the Navy to study broad technical and policy questions relating to airships. Appointment of the Committee was prompted by the loss of the airship Macon. Three comprehensive reports were made to the Secretary of the Navy over a period of three years.

In 1941, at 82 years of age, Durand was called from retirement to serve as a member of the NACA in order to perform a special service. It is reported that when Dr. Vannevar Bush, then Chairman of

NACA, requested President Roosevelt to make the appointment, the President suggested that a man of this age should be allowed to enjoy his retirement and a younger man sought. Bush was persuasive and Dr. Durand was duly appointed a member of NACA and named to head a Special Committee on Jet Propulsion. I had the privilege of serving on this committee under his leadership.

The appointment of this Committee was requested by General H. H. Arnold, Chief of the Air Corps, and also a member of NACA. He wrote to Bush on February 25, 1941 citing intelligence reports of German activity in rocket propulsion and the Committee was established in March. The Committee included industrial representatives from turbine manufacturers but not from the aircraft engine companies who were busy with war production. These industrial representatives studied the problem and brought in proposals for a ducted-fan engine, a turbo-propeller engine and a turbo-jet engine. Robert Schlaifer states, "It was apparently owing in large part to Durand, who was an exceptionally energetic chairman, that jet propulsion was very seriously considered by the committee." In September the Committee recommended that contracts should be given for the development of all three engines.

Shortly after General Arnold wrote his letter to Bush, he learned that gas turbines had been built and were on the point of being flown. Durand was early informed of this development but other members of the committee remained in ignorance for more than a year. By September 1941 arrangements were concluded with the British for manufacture of the Whittle engine in the U.S. by the General Electric Company.

Durand, the elder statesman, was thus the guiding spirit in stimulating research and in the initial guidance of industry in the development of the turbine engine in the U.S. during World War II.

As is now known, Heinkel in Germany ran a demonstration jet engine in March 1937 and made the world's first turbojet-powered flight in the He 178 on August 27, 1939. The first British Whittle engine was tested in the summer of 1937, the first suitable for flight, the W-1, was tested in December 1940, and the first British turbojet-powered flight was made in Gloster E 28/39 on May 15, 1941.

Durand's second period of service with NACA ended with his resignation in 1945. During this period he also served as Chairman of the Engineering Division of the National Research Council. For his guidance of the work on jet propulsion he received the Presidential Medal of Merit from President Truman.

Conclusion

The contributions of William F. Durand to aeronautics constitute but a limited part of his total contributions to science and engineering. (all of them made between his 55th and 85th year). The quality of his aeronautic contributions is attested by numerous awards and honors, the Guggenheim Aeronautic Medal, the John Fritz Medal of the four major U.S. engineering societies, the Franklin Medal of the Franklin Institute, the J. J. Carty Medal of the National Academy of Sciences, the ASME Medal, the Presidential Medal of Merit, and the first Wright Memorial Trophy "for important public service of enduring value to aviation in the United States."

Many of the citations epitomize the work and character of this great man. For example, the citation of the ASME medal reads, "For his contributions in hydrodynamic and aerodynamic science and its practical application, for his inspiring character and unique capacity for lucidity and simplicity in imparting highly technical material, for his trustworthy advice to our Government in the solution of many intricate problems, in peace and during two world wars." Or another which *specifically* appeals to me, the citation of the Carty Medal, "For notable leadership in engineering work, in his work a versatile and creative engineer, among his colleagues a wise and friendly counselor, before his students a kindly and inspiring teacher, to the nation a devoted and able servant." Such is the work and character of the man whose memory we honor today.

- [1] Army-Navy Journal, vol. 18, no. 14, p. 269, 1880.
- [2] Researches on the Performance of the Screw Propeller.
Carnegie Institution of Washington, Washington, D. C.,
1907, 61 pages. (Publication No. 70)
- [3] Adventures in the Navy, in Education, Science, Engineering
and in War. American Society of Mechanical Engineers
and McGraw-Hill Book Co., New York, 1953, 212 pages
(see page 56).
- [4] Development of Aircraft Engines and Fuels.
Robert Schlaifer and S. D. Heron. Harvard University,
Boston, 1950, 742 pages (see page 460).